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A DEVELOPMENTAL STUDY OF THE RELATIONSHIP BETWEEN REACTION-TIME AND PROBLEM-SOLVING EFFICIENCY. FINAL REPORT.

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MANY STUDIES HAVE INDICATED THE PRESENCE OF A SLUMP OR INVERSION IN THE PROBLEM-SOLVING EFFICIENCY OF CHILDREN AT THE FOURTH GRADE LEVEL. IT HAS BEEN SUGGESTED THAT THIS MAY BE DUE TO THE INTERFERING EFFECT OF THE FORMATION OF COMPLEX HYPOTHESES BY THE CHILDREN. SINCE A TENDENCY TO RESPOND RAPIDLY WOULD PRESUMABLY INHIBIT THE FORMATION OF COMPLEX HYPOTHESES, IT WAS HYPOTHESIZED THAT IF CHILDREN WERE DICHOTOMIZED INTO FAST AND SLOW RESPONDERS, THE FAST GROUP WOULD FAIL TO SHOW THE SLUMP. A TOTAL OF 168 STUDENTS, 42 IN EACH OF GRADES TWO THROUGH FIVE, WERE GIVEN A SET OF FOUR SEQUENCE-DETERMINATION PROBLEMS. THE AMOUNT OF TIME THE STUDENTS TOOK TO COMPLETE A SERIES OF 50 TRIALS ON EACH PROBLEM WAS USED TO DIVIDE EACH GRADE INTO FAST AND SLOW RESPONDERS. FOR THE COMPLETE SAMPLE, THE PERCENTAGES OF CHILDREN SUCCESSFULLY DETERMINING EACH SEQUENCE SHOWED THE EXPECTED INVERSION FOR THREE OF THE FOUR PROBLEMS. HOWEVER, WHEN THE SAMPLE WAS DIVIDED, THE SLOW RESPONDERS SHOWED AN INVERSION FOR ALL PROBLEMS. BUT THE FAST RESPONDERS SHOWED AN INVERSION ON ONLY ONE PROBLEM. ALTHOUGH THE PREDICTION OF THE HYPOTHESIS WAS CONFIRMED, THE FACT THAT, AFTER THE SECOND GRADE, THE FAST RESPONDERS ALWAYS DID BETTER THAN THE SLOW RESPONDERS CLOUDS THE INTERPRETATION OF THE RESULTS. IT IS FELT THAT THE COMPLEX HYPOTHESIS ASSUMPTION IS INSUFFICIENT TO ACCOUNT FOR THE IMPORTANCE OF THE REACTION TIME VARIABLE. (DR)

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A Developmental Study of the Relationship between Reaction-Time and Problem-Solving Efficiency

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A Developmental Study of the Relationship between Reaction-Time and Problem-Solving Efficiency

INTRODUCTION

A number of studies have demonstrated that the expected continuous increase in problem-solving efficiency with developmental level shows an inversion at the 4th grade school level. In a series of studies of the ontogenetic development of creativity, Torrance (1961) found that of many processes studied, only the formulation of hypotheses concerning causation failed to show a 4th grade inversion. This finding was replicated by Yamamoto (1962). Friedman (1965), using sequential patterns in a concept learning task, found a continuous increase with grade in the percentage of children able to successfully solve the problems, except for an inversion at the 4th grade. This finding was subsequently replicated using the identical procedure with a different population (Friedman, 1966, 1967). Klugh, Colgan, and Ryba (1964) had earlier noted a developmental inversion when they studied a series of concept learning tasks using 1st through 4th graders. With relatively simple problems, even the 1st graders surpassed the 4th graders; the most notable drop in efficiency occurred on the simple-concept tasks between 3rd and 4th grades. When they modified the procedure (Klugh & Roehl, 1965), informing S "that there was a rule he could discover which would allow him to be right on every trial" (1965, p.385) and using a correction procedure so that when S made a wrong choice, he was informed of the correct choice, the inversion was approached only on the simpler task. However, since this study only included 5-6 year olds and 9-10 year olds, it cannot be considered a true

replication.

Though it certainly appeared that a real phenomenon had been discovered, the problem still remained that these results were contrary to what would be predicted from most theoretical positions regarding developmental learning. Friedman (1965) suggested that for a large number of children, perhaps a majority, the 4th grade is a time when they are at the peak of a transitional developmental level where the inexpert use of a newly developing problem-solving technique reduces intellectual efficiency. White (1965 b), discussing the evidence shown by a number of researchers that there is a decline after age 7 in discrimination learning, suggested (p.201) "...it is plausible that older children adopt complex hypotheses which actually interfere with their performance on simple problems." Similarly, Weir (1964, p.481) noted that the "...middle-aged child may be capable of complex hypotheses, but he is unable to make full use of the information available from his own responding. This...explanation would suggest ...the 7- to 10-year-old is at a point in development where his ability to generate complex hypotheses and employ complex search strategies is growing at a faster pace than his information-processing ability, which catches up only at a later age." The point common to these speculations is that the decline in problem-solving efficiency is due to the formation of overly-complex hypotheses concerning solution strategy. Some support is provided for this explanation by the fact that the only area in which Torrance (1961) failed to find the inversion was hypothesis generation. The creation by S of unnecessary complexity obscures the basically simple nature of the task. From this

inference it follows that if some means were available to differentiate those Ss who themselves tend to inhibit complex hypotheses, we should observe the disappearance of the 4th grade inversion.

An approach to this methodological problem derives from various research sources not directly concerned with the present phenomenon. One view concerning learning posits the existence in S of a response hierarchy for any problem situation. This approach suggests "that if the solution response is high in the hierarchy of responses elicited by the problem stimulus, S's first guess at the solution response will more likely be correct than if the solution is lower in the hierarchy" (Duncan, 1966, p.147). Duncan found that when he used a verbal association task requiring either the first associate or second associate word (as determined by normative data) as the correct response to a stimulus word, the results were predicted by the response hierarchy approach to learning.

White (1965 b) has analyzed the <u>temporal</u> aspects of the response hierarchy. He used a procedure whereby the S was asked to make one response to a training stimulus and another to any other stimulus, so that a latency measure might be obtained when an S made either a generalized or a non-generalized response to a test stimulus. Thus S might be instructed to make Response A to Stimulus 1, and Response B to any other stimulus. These other stimuli could be graded with respect to their similarity to Stimulus 1 along some relevant dimension, such as color (i.e. wavelength). In these terms, Response A to any stimulus other than Stimulus 1 would be a generalized response, an error. (Similarly, Response B to Stimulus 1 would be a generalized

response. However, this particular sort of generalization would be unlikely, since Response A is the training response and, therefore, has greater habit strength and a higher probability of occurrence.) The usual reaction-time procedure offers S a respond-do not respond choice, and the latency of a correct response to a test stimulus cannot be taken because the correct response to a test stimulus is no response. The 2-response technique eliminates this difficulty.

White then found that an error response on a test trial (i.e. Response A to a stimulus other than Stimulus 1) was usually of significantly shorter latency than a correct response (i.e. Response B). Further, he found that the faster subjects gave more generalized responses (i.e. Response A to test stimuli) than slower subjects and the responses of any subject were faster when they were generalized than when they were not.

He concluded (White, 1965 a, p.274), "The influence of short- or long-latency responding upon the generalization of a voluntary response suggests that the phenomenon is associated with temporal response priorities." The effect of short-latency responding was to produce approximately 80% errors. Since mere random responding would lead (in a 2-choice situation) to 50% errors, it was clear that the consequences of quick responding were systematic and an indication that alternative responses exist according to some temporal hierarchical system. White had developed his concept of such a system (1965 b, p.194): "One could image a series of n responses strung along a time so that each response has its own modal locus.... There is another possible interpretation of the temporal stacking mechanism, however, which is

that in essence there are only two zones -- a zone of automation and a zone of decision. If, through prolonged training, a response is drilled in to a particular cue, it is possible that such a response becomes established in an automation system which has privileged, short-latency, access to response selection. If the subject senses novelty and/or an unpleasant event, he inhibits the automated system and switches to the decision system for determination of response. Here one response is first-available but, if this response is inhibited, selection of another response is decided not by temporal priorities among the remaining response alternatives but by reflective operations which can bring forth any of the alternatives as second-available in time.... Compromises between 'n-stacking' and 'two zone' hypotheses are conceivable, for example, the notion of a zone of automation containing several responses with different characteristic latencies, and a zone of decision out further on the time line."

Kagan (1966 a, p.17) commenting on the reliability of individual differences in temporal response characteristics, notes "Some children -- and adults -- select and report solution hypotheses quickly with minimal consideration for their probable accuracy. Other children, of equal intelligence, take more time to decide about the validity of solutions. The former group has been called impulsive, the latter reflective."

It seems likely, then, that quick responding should tend to inhibit the formulation of complex hypotheses, and foster the utilization of relatively simple cognitive processes. The credibility of this hypothesis is further strengthened by the work of Suedfeld (1966) who

studied the effect of input rate and pattern complexity on information processing in a word association task. He found that complex problems were solved more frequently than simple ones under a moderate input rate condition, whereas simple solutions were dominant under a high input rate. "Furthermore, the processing behavior itself became simpler under high rate" (p.249). Thus, if we were to dichotomize the Ss at each grade into fast-responding and slow-responding groups we should expect the Fast group to be more successful at inhibiting complex hypotheses and, therefore, not show the 4th grade inversion.

METHOD

Apparatus

The apparatus is shown in Fig. 1. It consisted of a display panel, painted light blue, 18 inches high and 17 inches wide, slanted back from the vertical at an angle of 27 degrees. On the panel were 4 rows of 5 sockets each. Above each socket was a light-bulb mounted behind a ruby-red glass shell. A series of blue cardboard masks were held in place by two brads protruding from the top corners of the panel-face. Each mask blocked all but one of the socket-light-rows from view at a time. No S was permitted to see more than one row at a time. A probe wire with pointer was connected at both the left and right rear of the panel; the one to be used by S during his series of trials depended on whether he was right- or left-handed.

Each row was programmed so that the lights could be activated in a predetermined sequential order by placing the probe-pointer in the proper sockets. Four sequential orders were used: 2,...; 4,2,...;

1,3,5,...; 3,3,5,... (the numbers refer to the socket-light pairs, reading left to right facing the panel).

In the first row, by placing the probe into socket #2, light #2 could be made to light; no other socket could turn on any light. In the second row, placing the probe into socket #4 turned on light #4 after which a relay activated socket #2 which could turn on light #2, then, when #2 lighted, a relay activated socket #4. The cycle would continue indefinitely, the two sockets never being activated simultaneously. Similar cyclical programs were set into the remaining rows: 1,3,5 in row 3; and 3,3,5 in row 4. Only one socket was ever activated at one time.

The apparatus was designed so that when a light turned on it would remain on for 3 seconds; this was done to ensure that any uncontrolled sources of distractibility would not be likely to affect the discriminability of a lighted bulb.

Instructions

S was seated in front of the display panel, and E asked him with which hand he wrote. S was then given the proper probe wire to hold. All other pertinent information had been previously gotten from the teachers.

All Ss were then given the following "neutral" instructions: "You see there are 5 holes and just above each hole is a red light. Well, sometimes, if you put this pointer in a hole, the light above that hole will go on and light up. You will have many chances to put the pointer in any of the holes you want. You can put it in all the holes if you

want to, but you don't have to if you don't want to, and you can put it in any hole as many times as you want. You only put the pointer in a hole if you think the light will go on above that hole. Your job is to find out how you can make a light go on each time you try. It doesn't matter where you make a light go on, but see if each chance you get you can make a light go on somewhere. Two things you'll have to remember are: when you put the pointer in a hole, take it right out, don't leave it in the hole; and if a light should go on, then wait for it to go out before you continue. Any questions? (Any questions were answered by paraphrasing the above instructions.) When I say 'Go', you can begin, and then, after a while, I'll tell you to stop."

Scoring

After completing each series of 50 trials per sequence, S was asked which lights had turned on, and, after his response, the mask was changed and the next series of trials begun.

E, sitting to the right rear of S, noted on a score sheet each response made and, by means of a stop-watch, the time taken to complete each series of 50 trials.

Since the lights were set to stay on for 3 seconds and S was required to wait for the light to extinguish before he was allowed to insert the probe into the next socket of his choice, it was necessary that a certain portion of the 3 seconds expended each time a light was activated should be subtracted from the total RT for each sequence, otherwise, those Ss who made many correct responses would necessarily have exceptionally long RTs. Several Ss at each grade level were tested

to determine what observable responses were made during the 3-second waiting period, and it was found that, almost without exception, the probe was immediately moved into position at the next socket choice. This motor movement was found, on the average, to require 1 second. For this reason, S was given credit for 2 of the 3 seconds expended per lighting. RT was thus corrected for by the formula:

$RT_{corrected} = RT_{actual} - (\#\ lightings)\ (2\ seconds)$.

Performance-Criteria

A correct response was considered to be one cycle of the sequence, in which each element produced a bulb-lighting. Thus, on the 2 sequence, any time socket #2 was chosen, light #2 lit up and S was given credit for one correct cycle of the sequence. On the 4,2 sequence, a correct response consisted of the choice of socket #4 (with light #4 turning on) immediately followed by a response to socket #2 (with light #2 turning on). Thus, the following series of responses: 4,4,2,1,5,3, 2,(4,2,)4,4,2; only contains one correct response, in parentheses, though six lightings (underlined) occurred. This is due to the fact that in two instances a correct response to #2 did not immediately follow a correct response to #4, rather there was an incorrect (i.e. no bulb lit) intervening response.

On the 1,3,5 sequence, similar scoring procedure held. For example, in the following series of responses: 2,4,1,2,3,5,5,3,(1,3,5,)3, 1,1,3,5; only one correct response was made though nine lightings occurred. The same procedure was followed for the 3,3,5 sequence.

Determination of criterion levels was done by first calculating

chance levels of correct responding in a series of 50 trials. This was done by means of the formula $(p_1)(p_2) \ldots (p_n)(50 \text{ trials}) = \text{number}$ of correct responses expected by chance. In this formula, "p" refers to probability; the subscript refers to the element in the sequence. Thus, for the 2 sequence: $(1/5)(50) = 10$; for the 4,2 sequence: $(1/5)(1/5)(50) = 2$; for both the 1,3,5 and the 3,3,5 sequences: $(1/5)(1/5)(1/5)(50) = .40$.

Using these figures as base levels, empirical determination was made, in a pilot study, of the relationship between the number of successful responses (i.e. sequence productions) and the S's apparent understanding of the nature of the sequence as revealed by intensive questioning. Each of a sample of Ss was tested with one of the sequences, and, after completion of 50 trials, S was questioned and asked to explain and demonstrate the nature of the solution. Then, cut-off points, in terms of objective response data, were determined which would best differentiate those Ss who seemed to have a clear grasp of the sequential property of the solution. The final levels chosen were: (equal to or greater than) 18; 3;3;3 correct responses; for the 2; 4,2; 1,3,5; 3,3,5 sequences respectively. It was found, however, that a minority of Ss had a tendency to "catch on" late in the series of 50 trials and thereby just miss the criterion level though questioning made it clear that they had grasped the nature of the sequence. For this reason the following supplementary criterion levels were included: (equal to or greater than) 10; 2;2;2; during the last 25 trials of each 50 trial series. In addition, the 1,3,5 and 3,3,5 sequences were considered correctly produced if two consecutive correct responses

were made during any portion of the 50 trials. This last provision was added so as to take into account those few Ss who might catch on quickly and, then, just as quickly, get bored and try out other ideas.

It should be clear to the reader at this point that the scoring criteria had as their main purpose the selection of those children who clearly grasped the nature of the sequence -- without regard to whether they persisted in repeatedly producing correct responses throughout each series of 50 trials. It was necessary to use objective data since S could not be questioned until he had completed all 4 sequences, at which time it would be virtually impossible to discriminate his initial understanding of each sequence.

Any S who reached a criterion level was considered as having correctly produced that particular sequence.

Subjects

Ss were from two Louisville Public Schools, both drawing children from predominantly lower-middle- and upper-lower-class families. Only male Ss were used and a requirement for participation was that S had never repeated a grade (i.e. that he be in the proper age-grade placement). This was done to keep age and number of years in school reasonably constant. One of the schools had the children at each grade level segregated into 5 groups (i.e. classes) each consisting of children of approximately equal general ability. Since the poorest group was so markedly below even the next-to-last class, it was decided not to use them in the study. It was felt that factors such as lack of directed motivation and ease of distractibility would overshadow any attempts

at solution. The deciding factor, however, was that not more than 3 or 4 children in each of these poor classed would have met the prerequisite for participation.

There were 168 Ss in all, with 42 at each of 4 grade levels: 2, 3, 4, and 5.

Statistical Treatment

The basic hypothesis in this study is that RT will have a direct and predictable effect on the shape of the developmental curve representing success at the solution of sequential problems. More specifically, the hypothesis deals with the relationship between this variable and occurrence of the 4th grade inversion. Thus, we are, in effect, predicting the shape, or trend, of each curve. However, since the measure being used is "percentage successful Ss at each grade level," we are left with only one score (i.e. percentage) per sequence per grade. This fact precludes the proper use of an analysis of variance or trend test. The appropriate test would be that of the interaction term in an analysis of variance. However, in the present instance, it is not possible to perform such a test, since the variation due to interaction cannot be separated from the within-cell variance.

It is possible, however, to compare the observed trend of the developmental curve with the predicted trend. Such a technique is limiting in the sense that the only estimate which can be made of the reliability of the results is the degree of consistency of results across the 4 different sequences.

RESULTS

Figure 2 shows that for 3 out of the 4 sequences there is an inversion at the 4th grade in the percentage of children who successfully produce the sequences. Thus, the basic phenomenon is replicated. As was pointed out in an earlier paper (Friedman, 1965), the children appear to approach the task with a predisposition for a 2-choice alternation solution; this may explain the fact that the 4,2 sequence again failed, as it had in the original study, to show the inversion.

The Ss were rank-ordered according to RT for each sequence at each grade level. Each ranking was then dichotomized into Fast and Slow groups. Figure 3 demonstrates that the Slow group shows an inversion at the 4th grade for all sequences, while for the Fast group, the 4,2 sequence shows a rise at the 4th grade; 2 and 1,3,5 level off from the 3rd to 4th grade, and only the 3,3,5 sequence shows the inversion. Figure 7 shows RT by grade, with sequences combined, for the Fast and Slow groups, separately and combined.

The mean difference in percentage of Ss reaching criterion between the Fast and Slow groups for all sequences was calculated for each grade. Since our assumption has been that the Fast group should outperform the Slow group (at least at the 4th grade), all differences have been treated as signed (i.e. #Fast - #Slow). Thus, a "+" indicates that the Fast group performed more successfully than the Slow group. The mean difference increases with grade; the 2nd grade has a mean difference of 0.00 percentage points; 3rd grade, +7.15 percentage points; 4th grade, +19.05 percentage points; and 5th grade, +25.00 percentage

points. A series of chi-square tests were run to test the significance of these Fast-Slow differences at each grade level. All four sequences were combined at each grade; this gave a sample of 84 scores each for the Fast and Slow groups (21 Ss X 4 sequences), the total N = 168. At the 2nd grade, $X^2 = 0$; 3rd grade, $X^2 = 0.85$; 4th grade, $X^2 = 6.3$; 5th grade, $X^2 = 10.8$. For d.f. = 1, $p < .05$, $X^2 = 3.84$; $p < .01$, $X^2 = 6.6$. Thus, the differences are not statistically significant at the 2nd and 3rd grade, but at the 4th and 5th grade, they are significant at the .05 and .01 levels, respectively.

In order to make any generalizations about changes in performance from sequence to sequence, the assumption must hold true that the Fast and Slow groups (within any one grade) are, for the most part, composed of the same Ss from sequence to sequence. For this reason, a series of chi-square tests were run comparing the distribution of the Fast-Slow groups on each sequence to their distribution on the immediately following sequence (i.e. 2 x 4, 2; 4,2 x 1,3,5; 1,3,5 x 3,3,5). Thus, there were 3 chi-square tests at each grade. It was found that 11 of the 12 comparisons were significant (i.e. the Fast and Slow groups tended to be composed of the same Ss from sequence to sequence -- the mean subject-overlap for the significant comparisons being 16.6 subjects, with a range of 15-20) at greater than the .01 level.

There was no consistent developmental pattern in terms of trials to criterion, except that the Fast group generally took fewer trials to criterion.

DISCUSSION

This study has had as its goal the testing of the hypothesis that

given essentially neutral instructions, fast responding Ss would not show the 4th grade inversion which would be found in the results of slow responding Ss. The hypothesis was comfirmed. Let us now consider the meaning and implications of these results.

Kagan, et al. (1964, p.33) found that "A tendency toward reflection versus impulsivity displayed a stability over time and a generality across tasks that is unusual for psychological attributes and tempts one to conclude that this disposition is a basic component of a child's behavioral organization." In a series of inductive reasoning tasks (Kagan, Pearson, & Welch, 1966 b), similar high intertask generality was found for response time. As was noted in the Results section, high relative (though not always absolute, as is seen in Figures 5 and 6) intertask reliability was found in the present study. So we can probably safely conclude that the temporal aspects of S's response system are reasonably stable across tasks and time.

Kagan, et al., place a further limitation on such a notion, however, by adding (1964, p.32) "It is to be noted that the high degree of consistency for response times is limited to this particular kind of problem (i.e., many response alternatives available simultaneously and the correct alternative is not immediately obvious). This consistency should not necessarily occur on tasks for which the alternatives are not quickly and simultaneously available. Response times to simple rote questions (e.g., What is your name? What is the month?); to difficult arithmetic questions; or on simple motor-reaction-time tasks should not necessarily correlate highly with each other.... Reflection does not refer to delay that is the result of failure, timidity, or

inability to generate any solution." Let us conceptualize these qualifications: they refer, basically, to differential knowledge, physiological differences among individuals, and emotional factors. With respect to the first two factors, S must, after all, possess certain minimal knowledge (e.g. language skills, arithmetic information, etc.) upon which solution depends, and he must be capable of making whatever physical responses are required.

The relationship between emotional factors and RT has only recently begun to be studied. Kagan, et al. (1966 b, p.594) state,"...informal observations indicate that a fair proportion of impulsive Ss do not seem anxious about a mistake. The possibility of being wrong does not elicit as much apprehension as it does in the majority of the reflective children." They attempted (Kagan, et al., 1964) experimentally to manipulate degree of anxiety by means of differential testing conditions; one condition, called "impersonal," was designed to make the test situation an anxiety producing experience; another condition, "reassuring," was designed to establish a friendly, warm test atmosphere. They concluded (p.27) "The minimal effect of impersonal versus reassuring testing conditions upon response and recognition errors suggests that these predispositions are not easily changed by experimenter rapport and are fundamental response tendencies in the child."

Fisher (1966) questions Kagan's assertion that "reflection" as a dimension is always distinct from failure to respond due to anxiety. She states (p.431), "Possibly such a child is not so much 'reflective' as anxiously indecisive. Perhaps one is dealing with hesitancy rather than ability to delay. Children who take time to make up their minds

may do so because of anxiety." Though Kagan may define 'reflection' as being distinct from delay caused by emotional factors, the empirical distinction is difficult to discover using availably techniques. In the present study, the assumption is that any emotional factors associated with the experimental situation are reasonably constant across grades.

Having noted these limitations, we may now discuss the more relevant correlates of the RT variable. The results indicated a developmental interaction between RT and task success. At the 2nd grade, RT had no apparent relation to task success, whereas, beginning at the 3rd grade, the faster Ss did better than the slower Ss, the size of the difference increasing steadily with grade. Kaplan & Mandel (1967) also studied the developmental effect of RT on concept learning. They randomly divided their Ss into two groups; one group was allowed to respond immediately, while the second group was told (p.3) "Don't do it yet. Think about it until I say, go ahead." The delay was 15 seconds. They used Ss at the 6, 8, 10, and 12 year levels, testing both lower- and middle-class children. They found that the forced delay had no differential social-class effect; unexpectedly, it had the effect of benefitting the 8 year olds, but hindering Ss at the other age levels. They concluded (p.4) "It would appear that 6 year olds cannot do much with the opportunity for more thoughtful working out of an approach and perhaps among the 10 and 12 year olds their approach is adequately integrated so that forced delay does not foster the process of shifting to new levels and may have an aversive effect." These results are similar enough to ours to make possible the inference that

a relatively fast RT may be, depending upon developmental level, indicative of superior cognitive activity. However, a seeming paradox emerges. Kagan has repeatedly found that (1966 b, p.594) "Impulsive children make more errors in inductive-reasoning problems...." He had foreseen the possibility of such apparently contradictory results arising, for he cautiously remarked (Kagan, 1964, p.35), "It seems reasonable to assume that efficient learning and performance on varied intellective tasks will sometimes be facilitated by a reflective or analytic approach; sometimes by a more impulsive or less analytic orientation."

Therefore, in addition to specifying S-characteristics (i.e. solution processes, emotional factors, response processes), we must specify, in some relevant and meaningful way, task variables. Of course, by holding the task constant, we may study the interrelationships among the S-variables, but we may not then generalize far beyond the type of problem situation used. Kagan, et al., note (1966 b, p.584) "...the most sensitive index of the reflection-impulsivity dimension is a test called Matching Familiar Figures (MFF). In this test the child is shown a picture of a familiar object, called the standard, and six stimuli, only one of which is identical to the standard.... The child is asked to select the one stimulus that is identical to the standard, and the standard and six variations are always available." This is, however, primarily a visual matching task which takes no great conceptual skill. By its very nature, the task makes it virtually impossible for S to quickly find the correct response, i.e. there is, in effect, a lower limit to the RT with which S may respond correctly. Thus, any S who tends to respond quickly in such a situation cannot possibly respond at

better than a chance level. So, perhaps the initial classification of task characteristics should be one specifying whether the problem is primarily "perceptual" or "conceptual". That is, does the task involve primarily "sensory processes" or "cognitive processes"?

At this point it is well to remember that our original hypothesis posited that the Fast Ss would not show the 4th grade inversion since rapidity would tend to inhibit complex hypothesis generation. The hypothesis was confirmed, but the assumption behind the hypothesis seems to be clouded, since the Fast Ss always (after 2nd grade) did better than the Slow Ss. There had been no inversion, for example, at the 5th grade, so why should the inhibition of complex hypotheses (if that is what fast responding accomplishes) have an even greater effect than at the 4th grade? The assumption is not contradicted, but these results indicate that the generation of complex hypotheses is probably only one of many factors precipitating the inversion.

In any case, the results of this study confirm the relevance and importance of the RT variable to conceptual behavior, though the assumption behind the hypothesis, that the demonstrated significance of the relationship between RT and the 4th grade inversion is due solely to complex hypothesis generation during the extended RT period, is obviously insufficient to fully account for the data. RT is a crucial factor, but it is still to be determined why it has such a major effect.

CONCLUSIONS, IMPLICATIONS

Reaction-Time has been shown to be a variable of major importance in the solution of conceptual problems; fast responding Ss do not show the customary 4th grade discontinuity in problem-solving efficiency.

The present study, added to the existing literature on the relationship between reaction-time and cognitive behavior, indicates that task variables must be specified and taken into account before reaction-time can be used to predict solution efficiency. Preliminary analysis suggests that an initial classification might be one stating whether the task is one whose solution requires primarily perceptual or conceptual processes. In the former case, there would appear to be a positive relationship between correctness of solution and reaction-time. In the latter case, the relationship would further depend on task complexity and developmental level of S. We had assumed that reaction-time would have its major effect through the facilitation or inhibition of complex hypothesis generation. This assumption was not supported by the data. So, though reaction-time has an important influence on conceptual behavior, the basis of this relationship is unclear.

SUMMARY

A number of studies have shown that in various concept learning tasks, 4th graders often perform less efficiently than 3rd graders. Several researchers have speculated that this inversion is a result of overly complex hypothesis generation by 4th graders. Such unnecessary complexity tends to obscure the basic simplicity of the tasks, thereby leading to inefficient problem-solving.

Presumably, if we could inhibit complex hypothesis generation, we should see the disappearance of the 4th grade inversion. Using 2nd, 3rd, 4th, and 5th grade males as Ss, we took advantage of the previously demonstrated direct relationship between Reaction-Time and complexity of conceptual behavior. It was assumed that slow responding Ss

generate more complex hypotheses than fast responding Ss.

The Reaction-Time variable did have the predicted effect; the fast responding group did not show the inversion which was found in the slow responding group. However, the results indicated that complex hypothesis generation does not fully account for the relationship between Reaction-Time and concept learning.

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FIGURE 1

THE APPARATUS

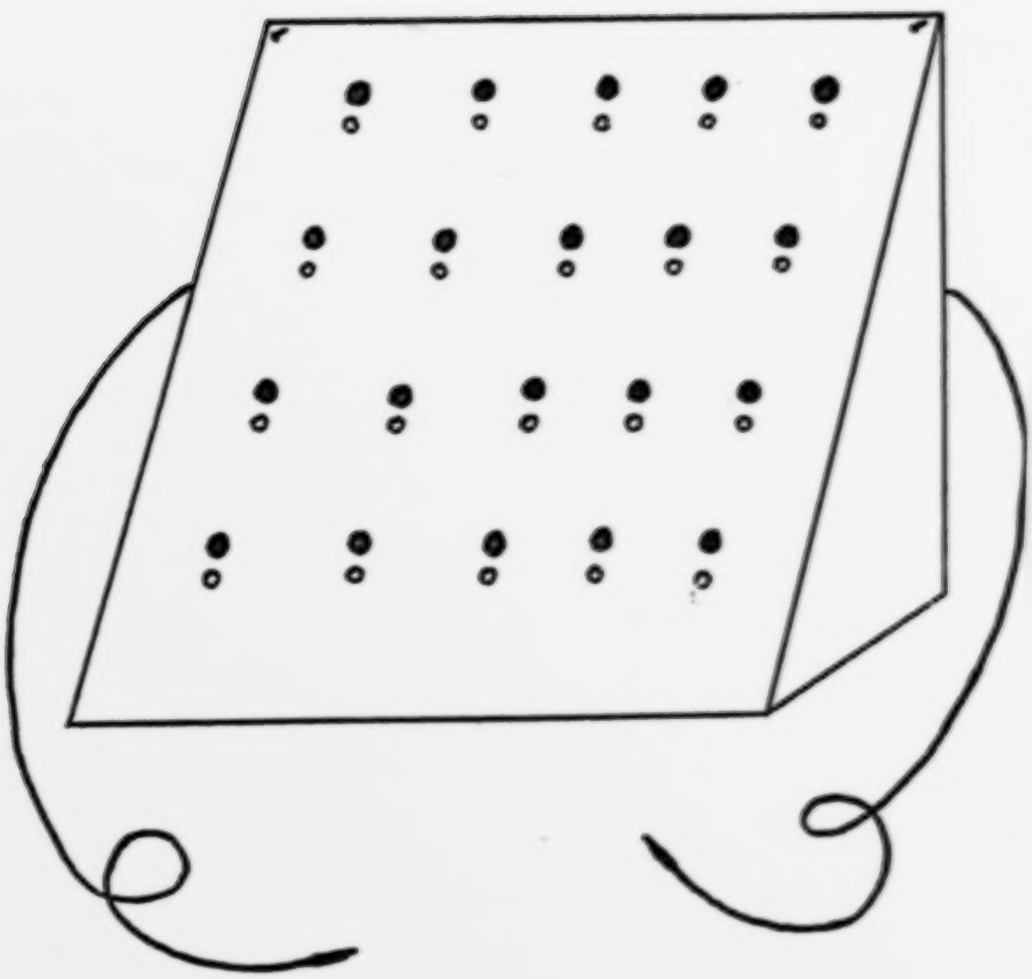


FIGURE 2

PERCENT SUCCESSFUL SUBJECTS AT EACH GRADE LEVEL

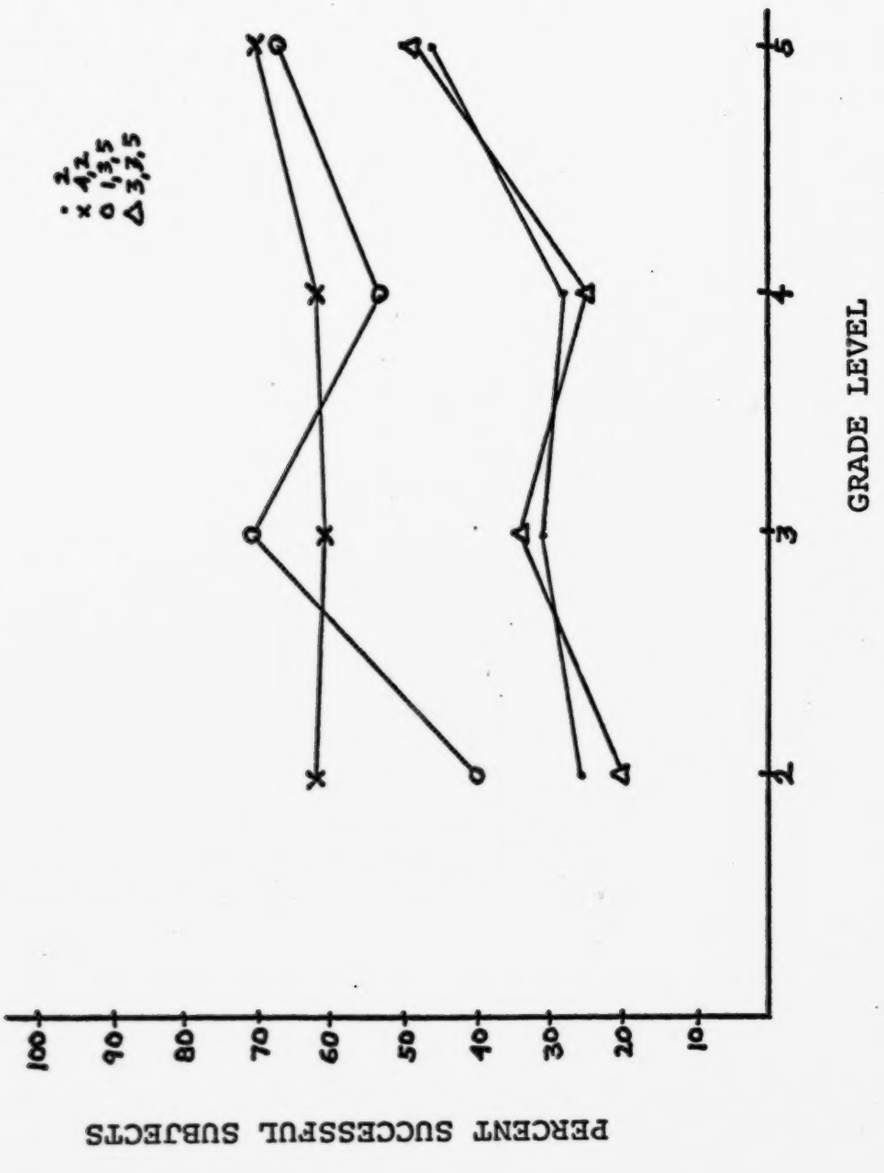


FIGURE 3

PERCENT SUCCESSFUL SUBJECTS AT EACH GRADE LEVEL

FOR FAST AND SLOW GROUPS

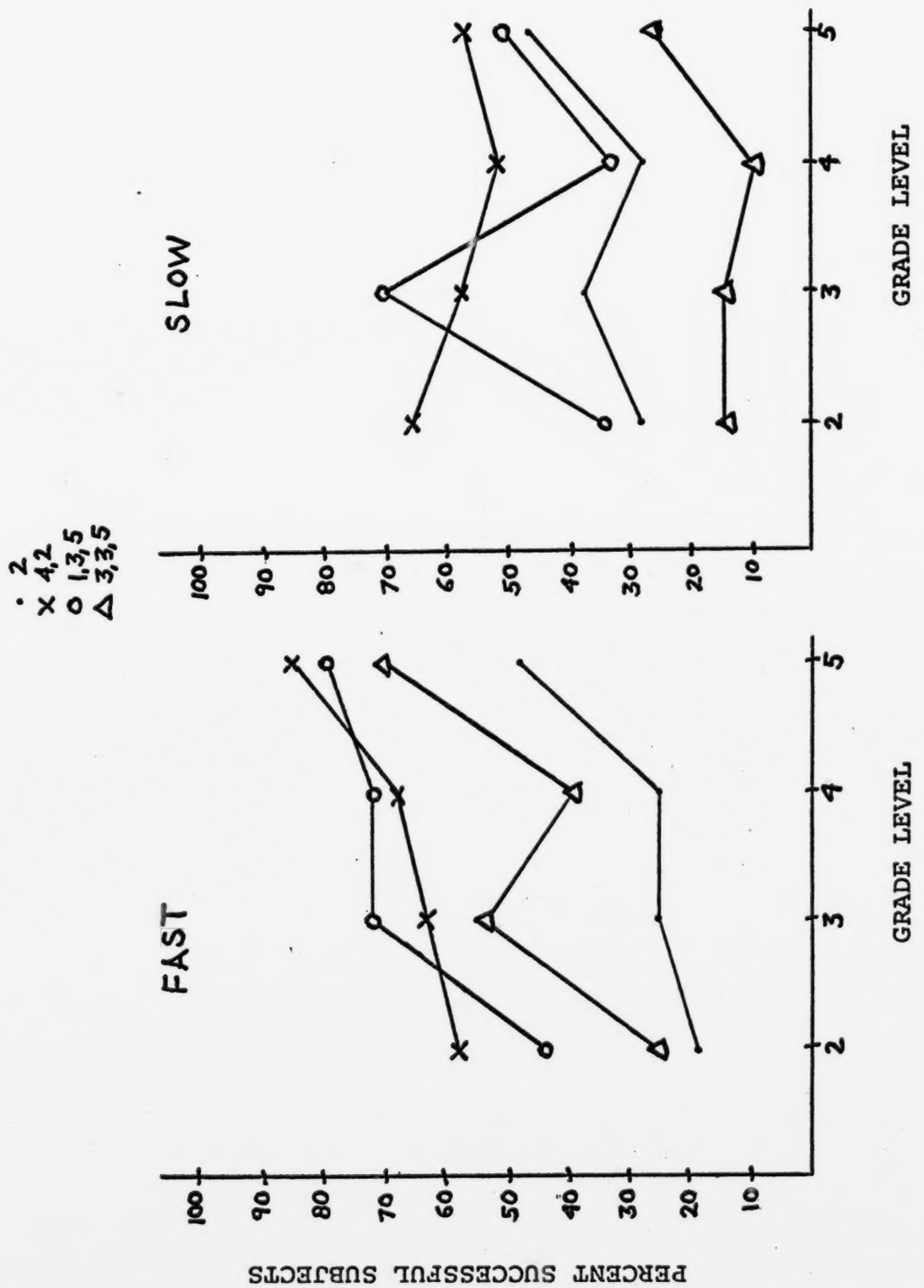


FIGURE 4

MEAN RT FOR EACH SEQUENCE FOR FAST AND SLOW GROUPS

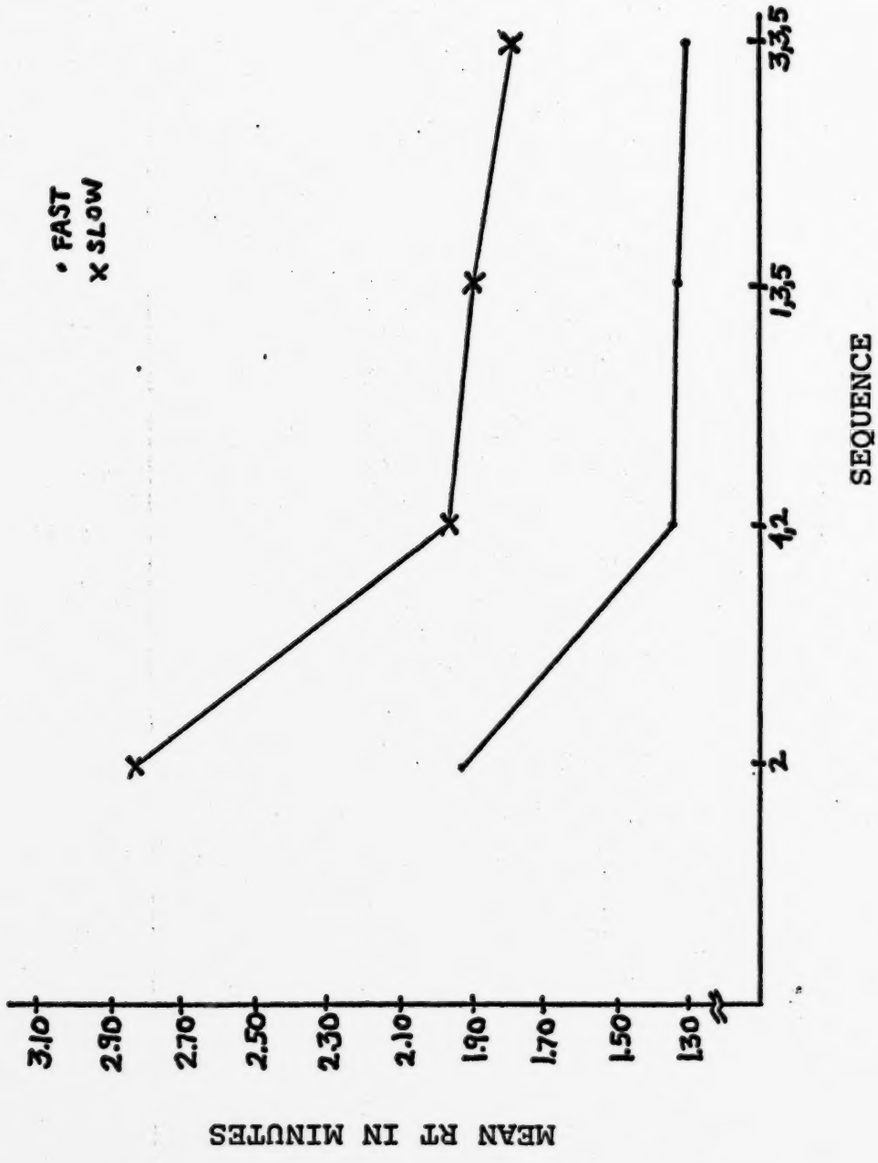
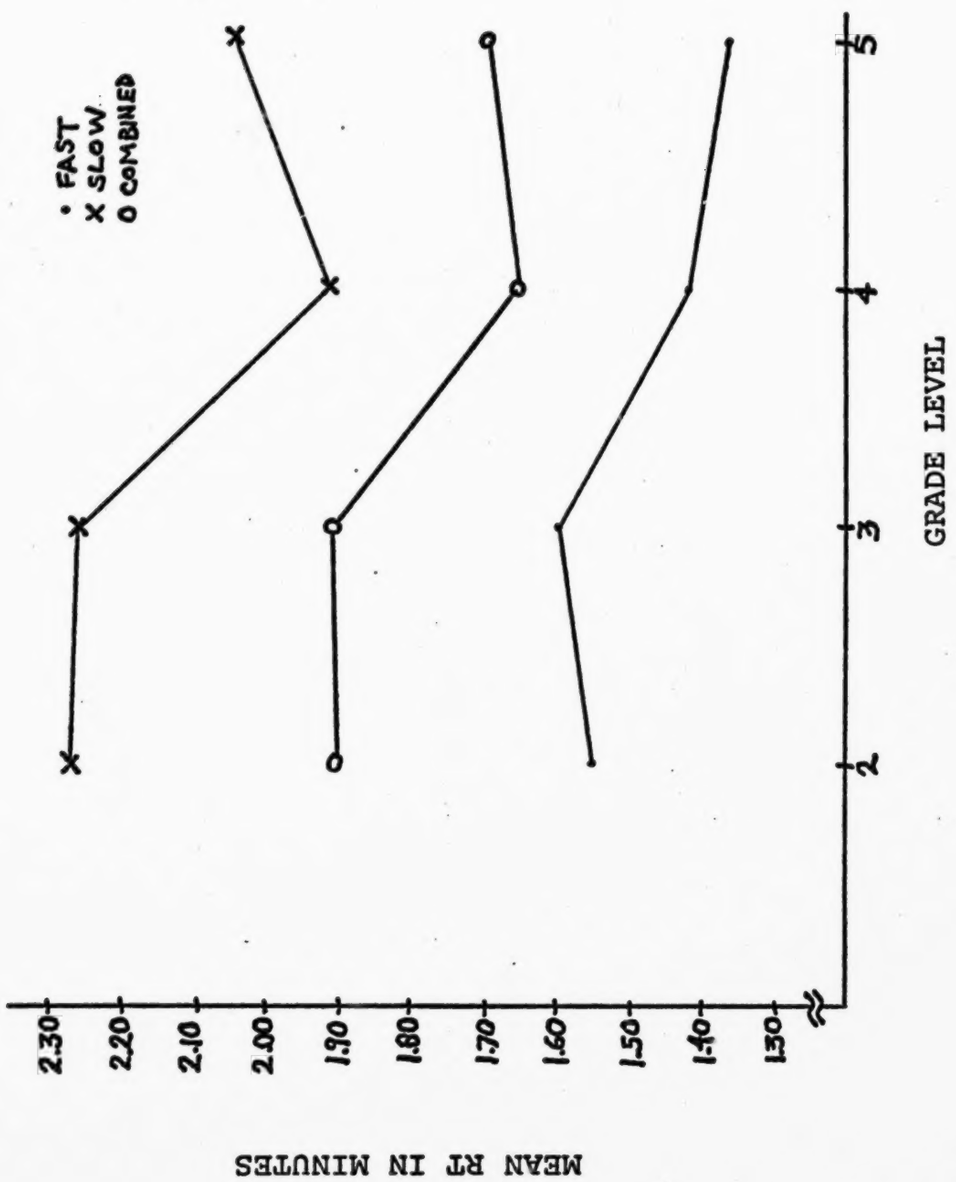


FIGURE 5

MEAN RT FOR EACH GRADE FOR FAST AND SLOW GROUPS,

SEPARATELY AND COMBINED



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